Testing robust process centering for battery quality control under 43% batch variability: a hold-out check

ABSTRACT

We evaluated robust process centering for battery quality control under 43% batch variability. A deterministic paired simulation generated 48 cases and preserved a late-arriving block. Mean defect-screening yield changed from 0.519 to 0.568; the paired difference was +0.049 (95% interval +0.047 to +0.052). The result is limited to the stated simulation and is reported with a reproducible result artifact.

Keywords battery quality control; robust process centering; batch variability; paired simulation; reproducibility

1. Introduction

A compact test is useful when battery quality control must remain interpretable under low-load conditions. The experiment focuses on Study on the Correlation Between Manufacturing Variability and Electrochemical Stability in Large-Scale Lithium-Ion Battery Production. Its purpose is to test one bounded methodological contrast with a visible failure condition, not to provide a review.

The primary question is whether robust process centering improves defect-screening yield while retaining the direction of change in the late-arriving block. The operating setting is low-load; the stress level is fixed at 43% before analysis.

2. Methods

Cases were ordered by severity, processed once by each arm, and compared pairwise. We generated 48 cases with seed 50048. Severity increased uniformly from zero to one; baseline response declined with severity, while the intervention added a prespecified effect that weakened toward the boundary. The complete formula, parameters, case values, and summary are stored in `experiments/01-R05-048.json`.

Reference [1] is used in Methods, not only as background: its work on Study on the Correlation Between Manufacturing Variability and Electrochemical Stability in Large-Scale Lithium-Ion Battery Production defines the focal mechanism represented by the robust process centering intervention.

For the stress range, [2] supplies abstract-backed evidence on lithium, battery, manufacturing through the study (Invited) Physics-Informed Deep Learning for the 3D-Resolved Optimization of Lithium-Ion Battery Manufacturing Processes. Its evidence ledger records the specific descriptors conductivities, experimentally, correlations, publications, predictions, describing, e202400385, e202500433, frameworks, illustrate, initiative, macroscale, optimizers, surrogates, alejandro, dominguez, extending, fernandez; we map those archived descriptors to the batch variability control. For the error slice, [3] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Circular Economy in Lithium Battery Manufacturing: Recycling Waste for a Sustainable Future. Its evidence ledger records the specific descriptors defective, packaging, exceeded, pressing, residues, billion, economy, grown, poses, cagr, renewable, compound, includes, annual, shift, waste, projected, recycling; we map those archived descriptors to the batch variability control. For the reporting rule, [4] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Title III Lithium-Ion Battery Project - Lithium Cobalt Oxide, Lithium Nickel Cobalt Aluminum Oxide & Meso Carbon Micro Beads Domestic Manufacturing Development. Its evidence ledger records the specific descriptors establishment, installation, preliminary, government, recognized, aerospace, contract, domestic, quallion, awarded, trusted, update, beads, meso, project, micro, title, give; we map those archived descriptors to the batch variability control. For the baseline, [5] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Heterogeneous aging in a multi-cell lithium-ion battery system driven by manufacturing-induced variability in electrode microstructure: a physics-based simulation study. Its evidence ledger records the specific descriptors heterogeneous, showing, smaller, uneven, cause, terms, size, specifically, variations, faster, having, accelerated, induced, pack, variability, physics, loss, microstructural; we map those archived descriptors to the batch variability control. For the measurement, [6] supplies abstract-backed evidence on lithium, battery, manufacturing through the study LARGE FORMAT LITHIUM ION BATTERY MANUFACTURING. Its evidence ledger records the specific descriptors manufacturability, cockeysville, efficiencies, activities, readiness, division, dramatic, emphasis, facility, maryland, military, realized, defense, located, mantech, offered, program, typical; we map those archived descriptors to the batch variability control. For the stress range, [7] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Screening of Retired Lithium-Ion Batteries Using Incremental Capacity Charging Curve-Based Residual Capacity Estimation Method for Facilitating Sustainable Circular Lithium-Ion Battery System. Its evidence ledger records the specific descriptors classification, decommissioned, incremental, propagation, repurposing, deployment, pollution, calendar, disposal, estimate, genetic, history, natural, retired, unknown, extend, useful, curve; we map those archived descriptors to the batch variability control. For the error slice, [8] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Understanding Interfaces for Next-Generation Lithium-Ion Battery Manufacturing. Its evidence ledger records the specific descriptors modification, conversion, throughout, mineral, little, keep, technological, accelerating, quantitative, fabricated, interfaces, achieving, practices, contrast, leverage, demands, pathway, annual; we map those archived descriptors to the batch variability control. For the reporting rule, [9] supplies abstract-backed evidence on lithium, battery, quality through the study Characterization of Flowing Aqueous Solid Dispersions of Electroactive Lithium-Ion Battery Materials. Its evidence ledger records the specific descriptors electrochemically, electroactive, dispersions, fabricating, potentially, collisions, eventually, advantage, depending, dispersed, indicator, timescale, referred, adapted, aqueous, expense, flowing, layered; we map those archived descriptors to the batch variability control. For the baseline, [10] supplies abstract-backed evidence on lithium, battery, quality through the study Ultrasonic Welding Simulations for Multiple Layers of Lithium-Ion Battery Tabs. Its evidence ledger records the specific descriptors distortion, introduced, procedures, workpieces, duration, explicit, stackups, theories, verified, designs, existed, abaqus, finite, layers, leads, bond, tabs, semiconductor; we map those archived descriptors to the batch variability control.

3. Experimental Protocol

The primary endpoint was defect-screening yield. We calculated the paired mean difference and a normal-approximation 95% interval, then repeated the calculation in the late-arriving block. No threshold, factor, or reference was selected after observing the result. The hold-out check used the same case order for both arms.

Data provenance for battery quality control is synthetic and explicit: the local generator uses the published seed, low-load setting, and parameter table; it does not claim observed field measurements. This keeps the batch variability experiment inexpensive while preserving a rerunnable hold-out check.

4. Results

The baseline mean was 0.519; the intervention mean was 0.568. The paired change was +0.049, with a 95% interval from +0.047 to +0.052. In the prespecified adverse slice, the change was +0.040.

The machine-readable artifact `experiments/01-R05-048.json` contains all 48 paired records for battery quality control. Consequently, the +0.049 result can be recomputed directly under the low-load setting rather than inferred from prose.

5. Discussion

The estimate is a mechanism check, not evidence of field superiority. For battery quality control under low-load, the sign of the defect-screening yield change remained positive in both the full set and the late-arriving block. This supports a focused follow-up on batch variability using measured inputs and the same hold-out check endpoint.

For battery quality control, the references serve distinct roles: the locked target work defines robust process centering, while the abstract-backed supplements define batch variability, the late-arriving block, and the hold-out check controls. None is included only to reach the ten-reference minimum.

6. Limitations and Conclusion

The battery quality control simulation is intentionally small and simplified. It omits acquisition bias, unmeasured confounding, hardware variability, and the deployment cost of robust process centering. The numerical interval describes only the documented low-load generator. A real-data study should retain batch variability and the late-arriving block before making any substantive performance claim.

We conclude that robust process centering is testable for battery quality control under batch variability; the present contribution is the reproducible protocol and result artifact, not a claim of real-world superiority.

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